Cone Simulations

Strategy

- Module 0: open Cones (pyramid), Al + Vikuity foil, „Stucki design“ -> done
- for tests: solid pyramids, cut, N-FK5
- 3/5 deg: parabolic shape, solid from mould? (more ideas to be tested in simulations)

Solid Prototpes

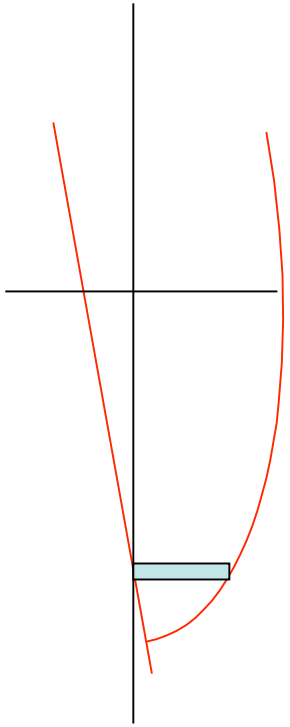
simple pyramid cone
made from N-FK5 glass
(cut & polished, ETH)

hex-square geometry
made from plexiglass
(cut, UZH)

Area concentration

Liouville theorem -> larger conc. in area ->
larger var. in angle

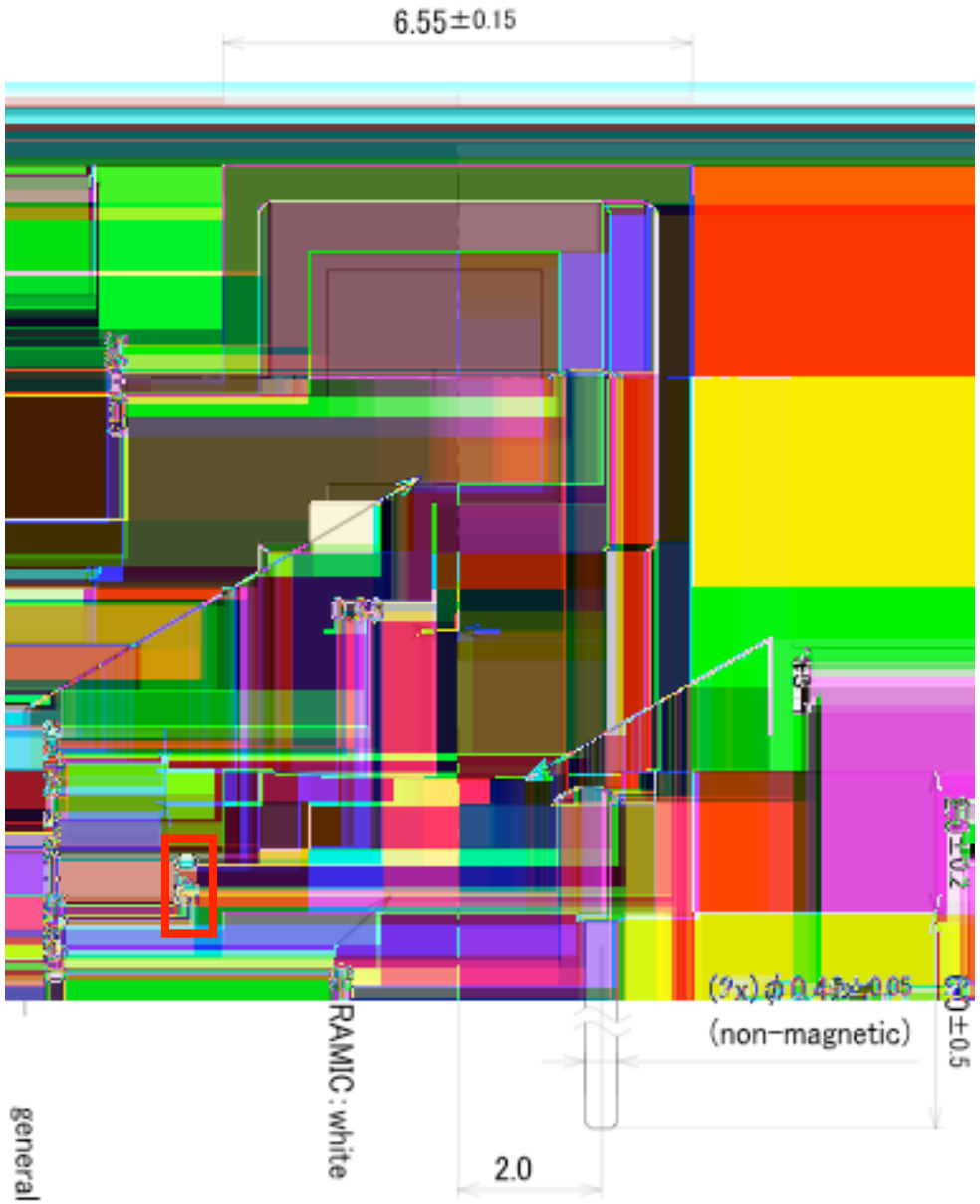
original Winston Cone:



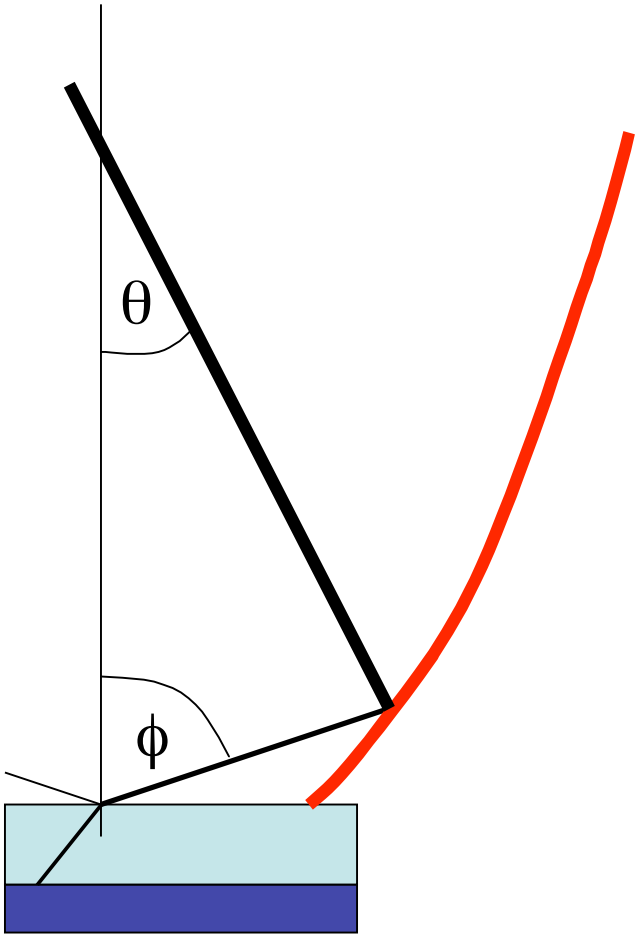
traditionally: highest reasonable
concentration is factor of 2 in area

but: can accept smaller incidence angles!

Material



Simulation



reflection on Cone surface (input: reflectivity)

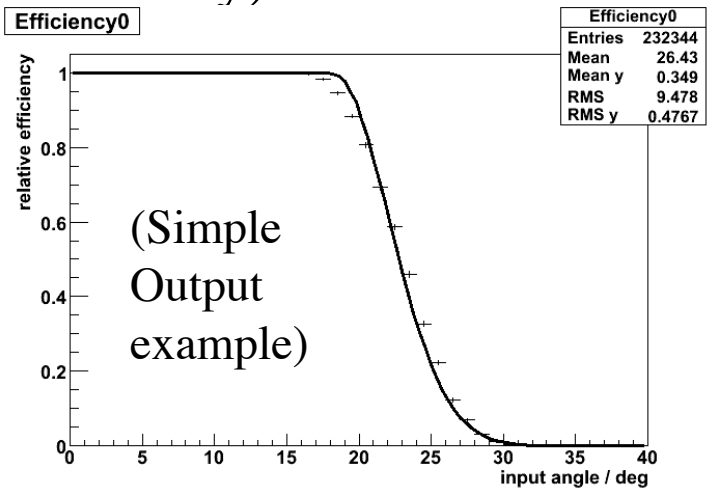
refraction when medium changes
(medium-keys, defined in code)

Fresnel reflection (w/o polarization)
wavelength dependent absorbtion

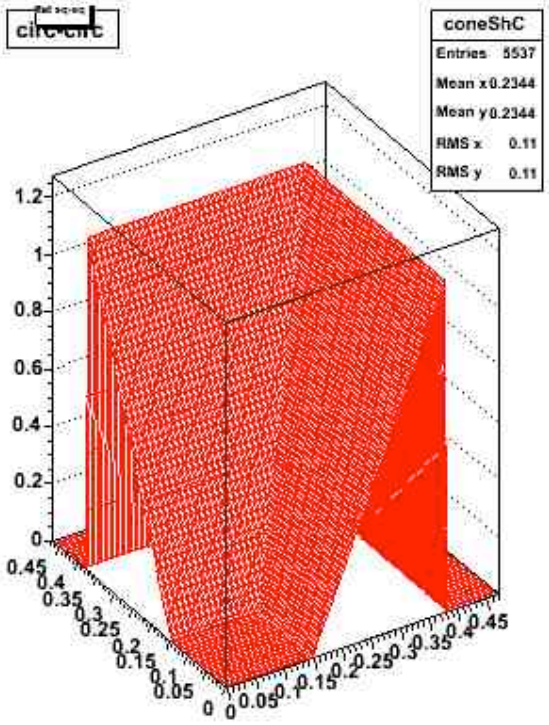
detector geometry (resin , I(λ, ϕ))

measured detector acceptance (ϕ, λ)

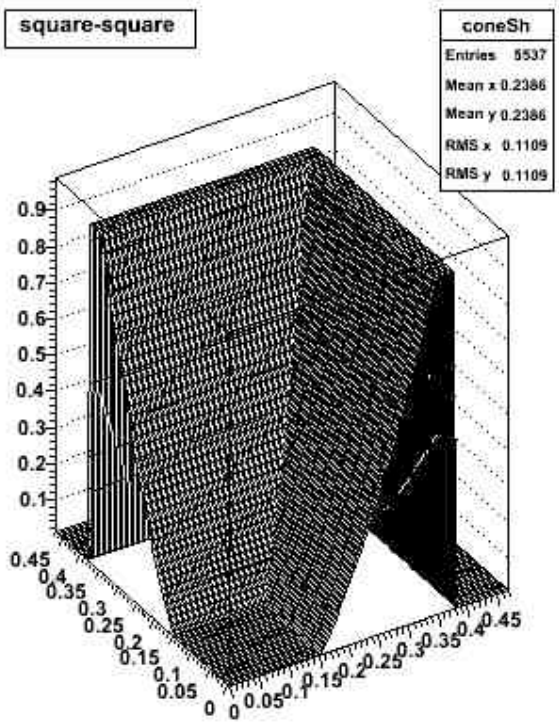
reflection (input: reflectivity)



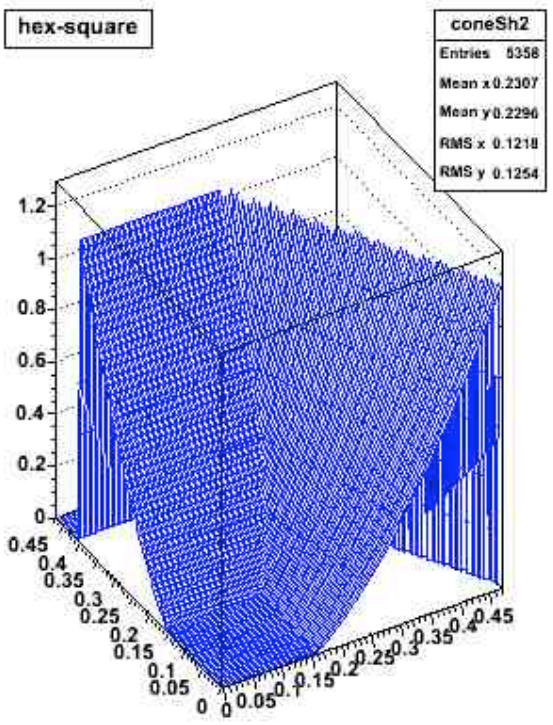
Simulated Geometries



square-square,
flat sides

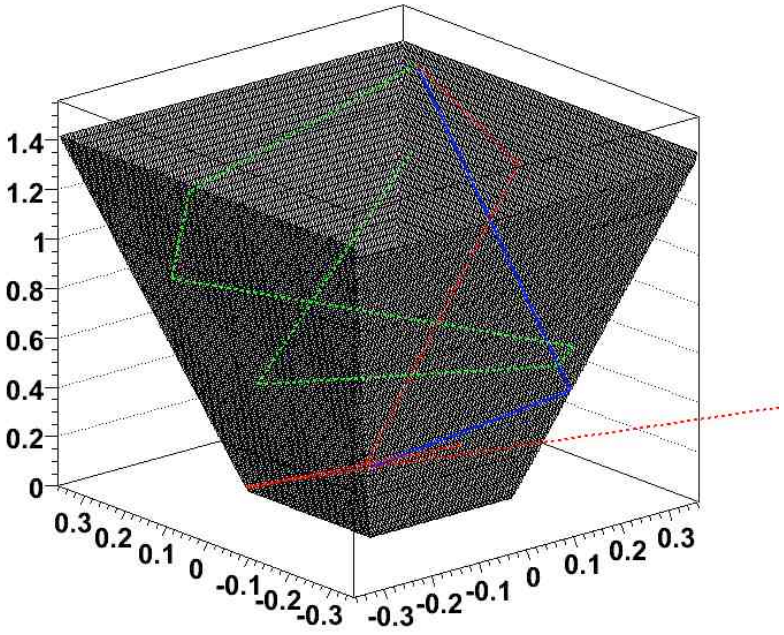


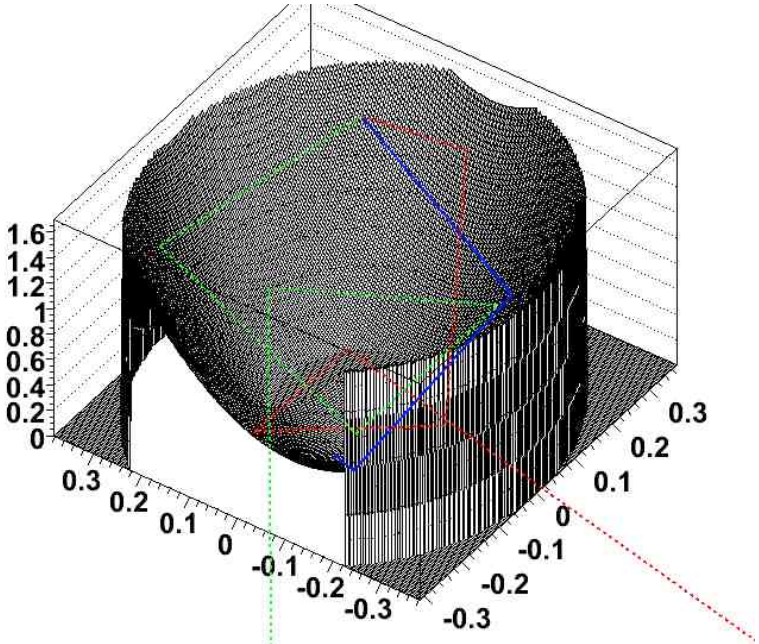
square-square,
parabolic sides

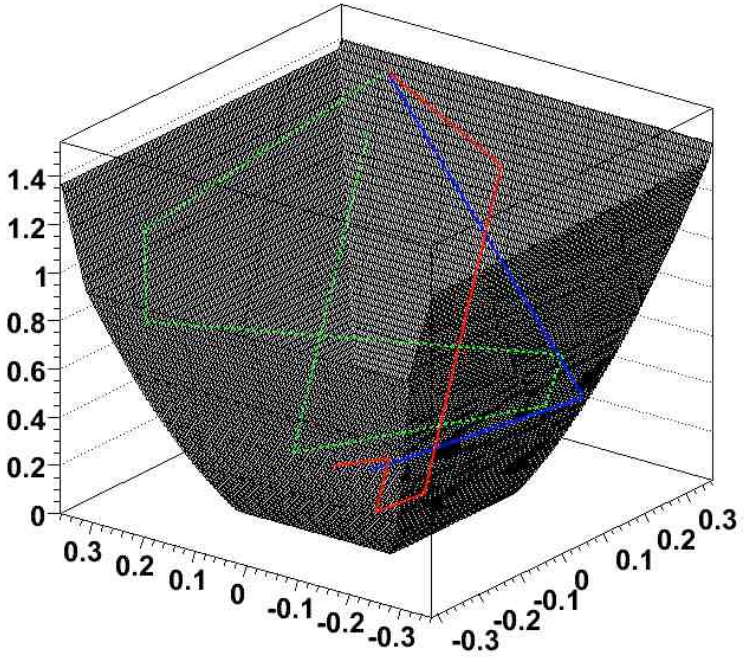


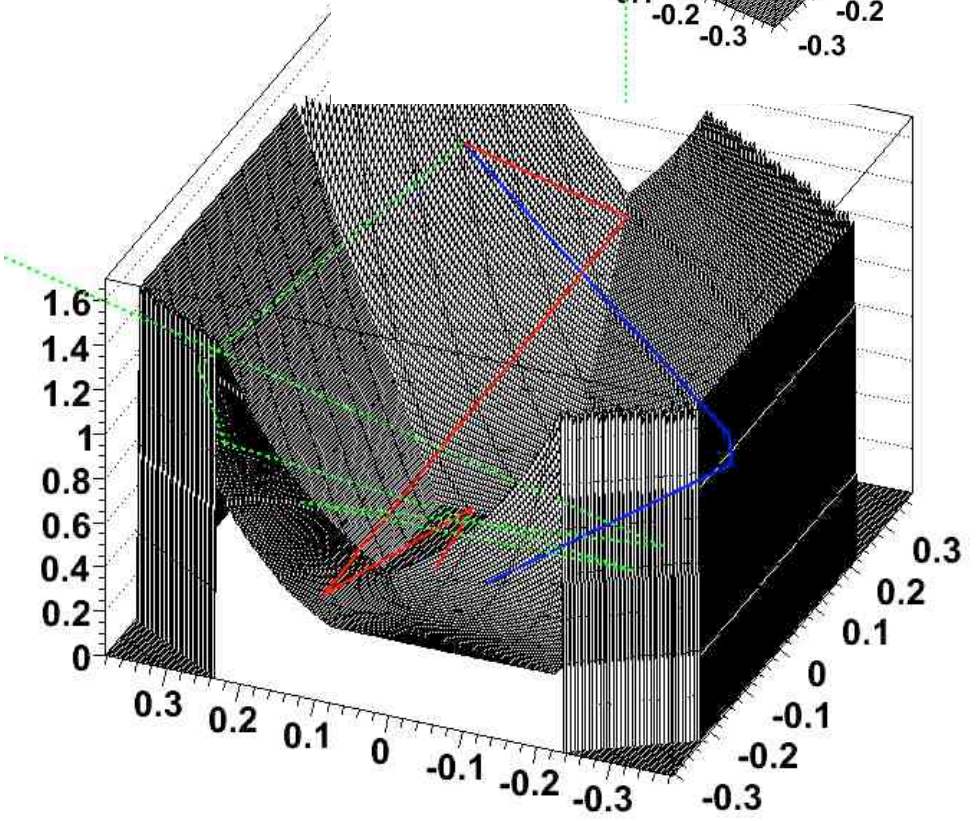
hexagonal-square,
parabolic sides

(and also circular-circular for reference)


1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.3 0.2 0.1 0 -0.1 -0.2 -0.3
-0.3 -0.2 -0.1 0 0.1 0.2 0.3

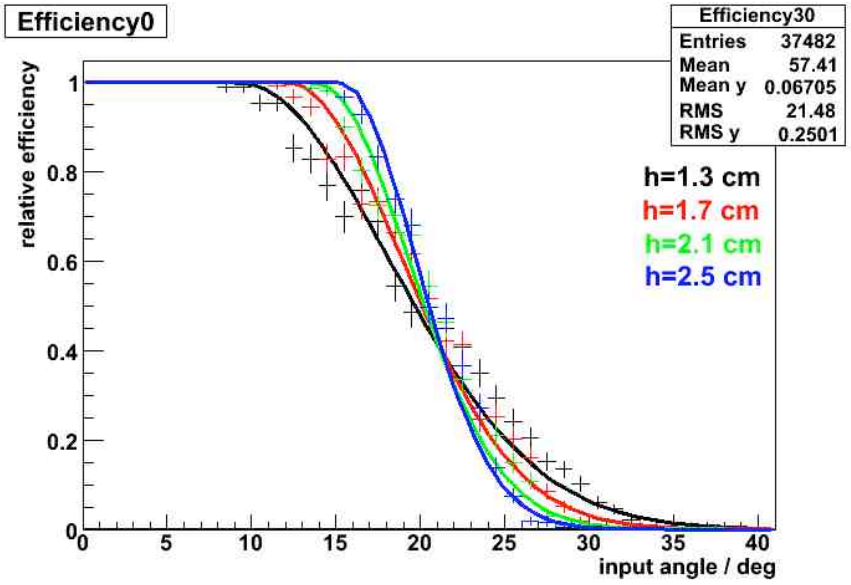

1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.3 0.2 0.1 0 -0.1 -0.2 -0.3
0.3 0.2 0.1 0 -0.1 -0.2 -0.3

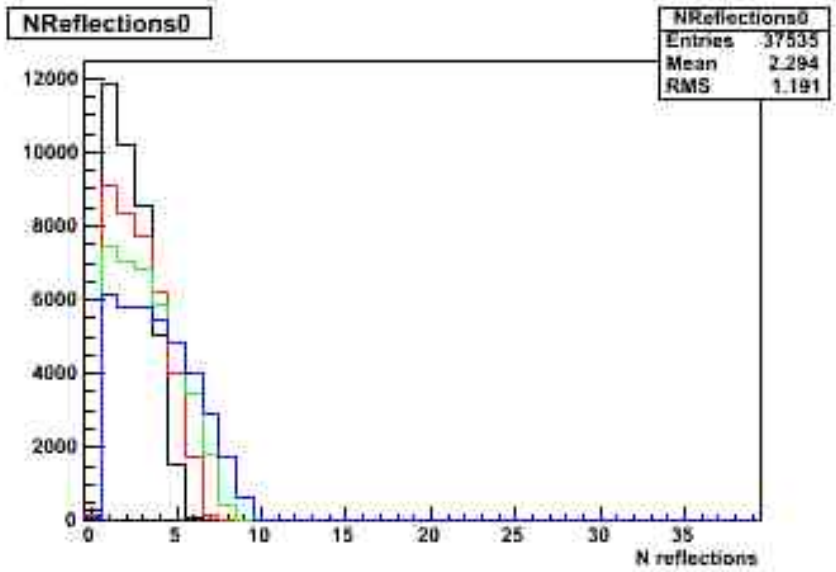

1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.3 0.2 0.1 0 -0.1 -0.2 -0.3
-0.3 -0.2 -0.1 0 0.1 0.2 0.3


1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.3 0.2 0.1 0 -0.1 -0.2 -0.3
0.3 0.2 0.1 0 -0.1 -0.2 -0.3

General Results

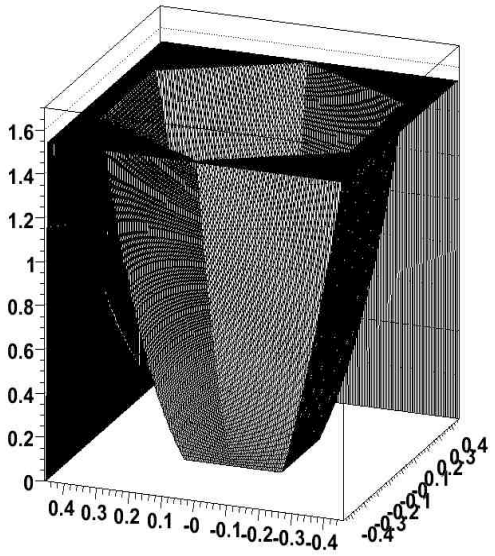
cone height:
- changes shape of cutoff
- little influence on position
- optimum depends on reflectivity

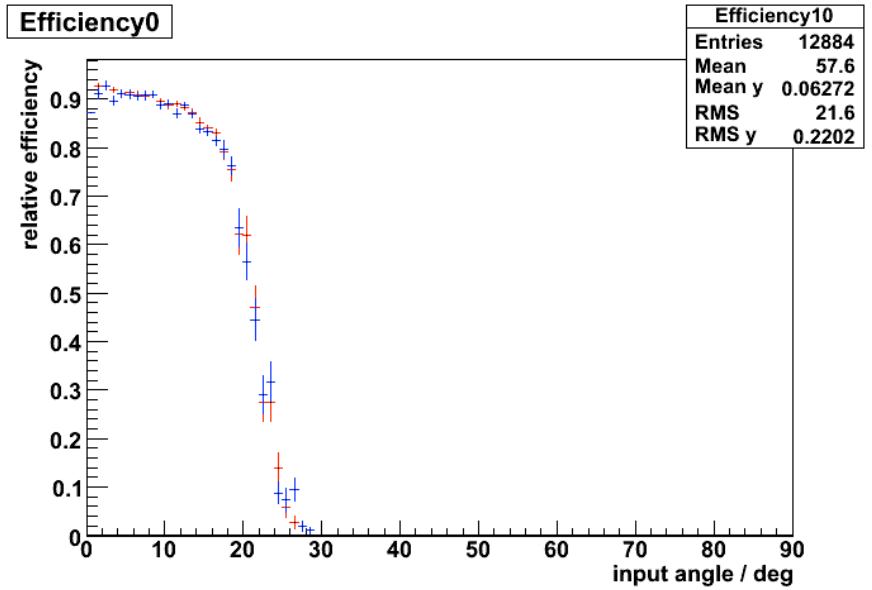




General Results

cone shape:
- parabolic walls
- hex-square possible without losses
- same input area:solids gain signal, but loose S/N for same h



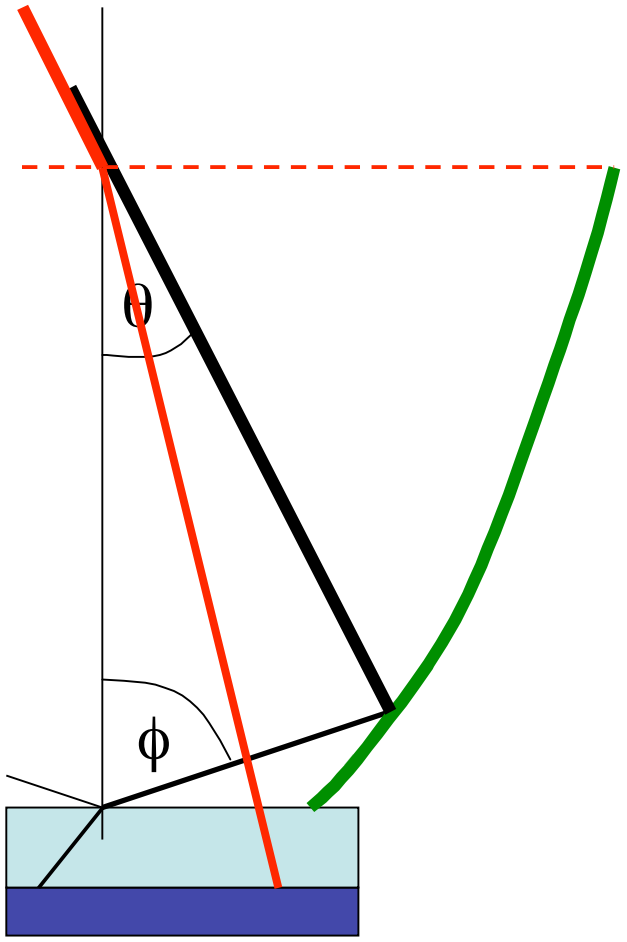


Solid Cone Differences

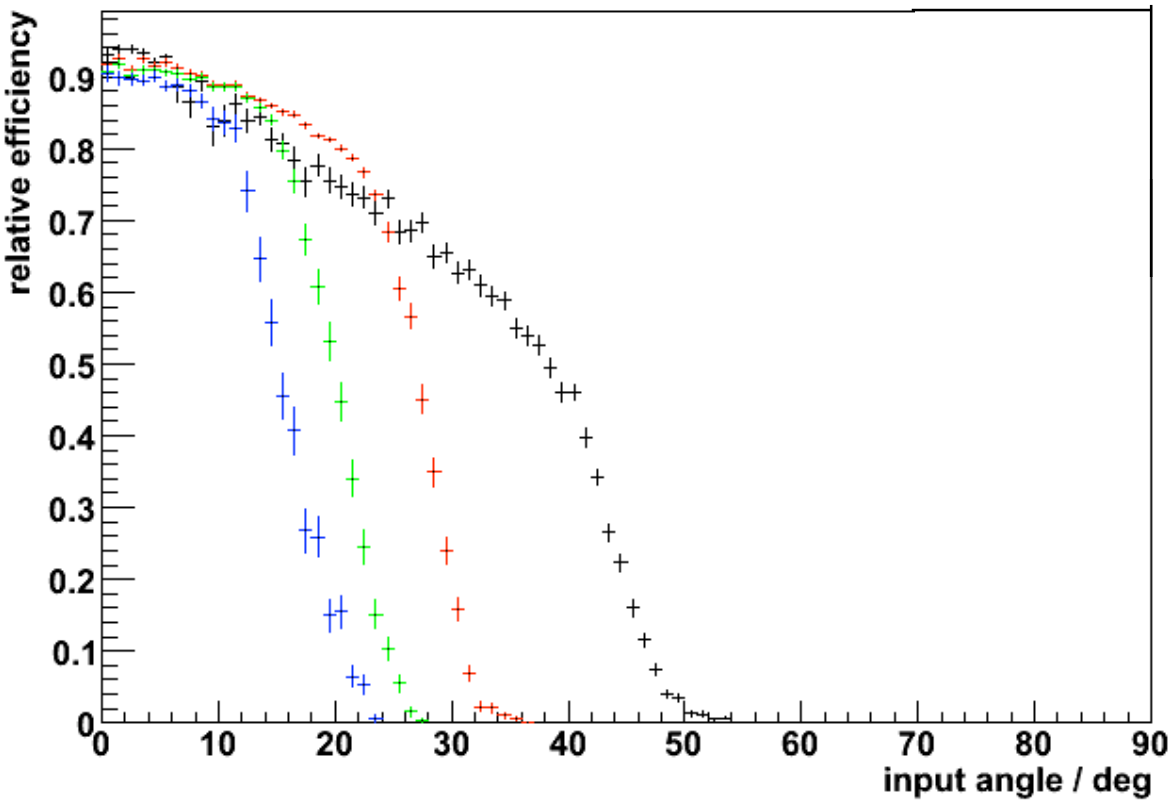
Primary refraction -> larger input angles accepted

typical caveats:
- false traces by muons -> high line signal
- UV transmittance -> select material
- more NSB

Benefits:
- larger collection efficiency
- protection of light sensor
- less Fresnel reflection
  than at layer near detector
- mass production



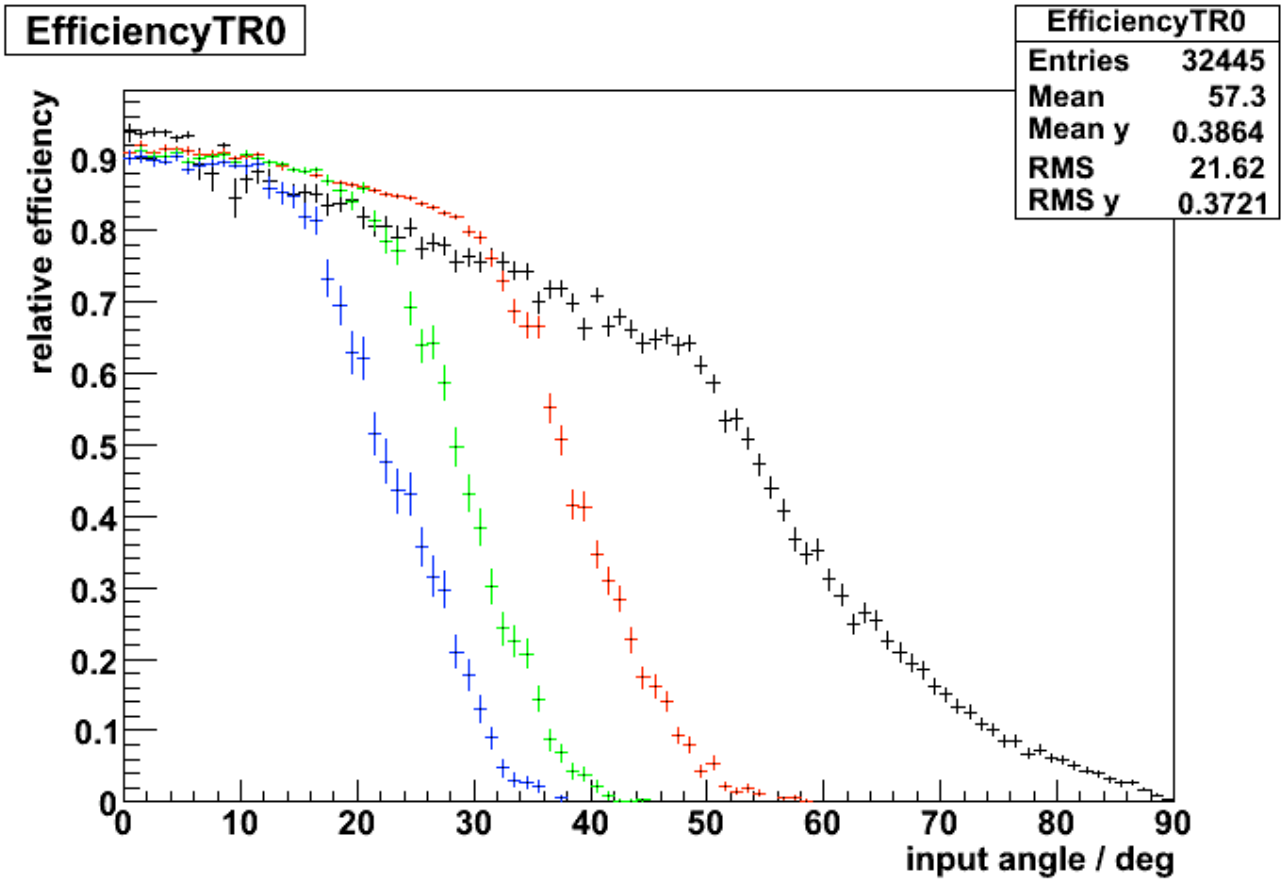
Area concentration - empty cones



Di/mm	factor	ε/%
4	1.9	82.3
6	4.3	86.4
8	7.6	78.6
10	11.9	57.1

hex-square
R = 95%
Do = 2.7 mm
h = 20 m

Area concentration - solid cones



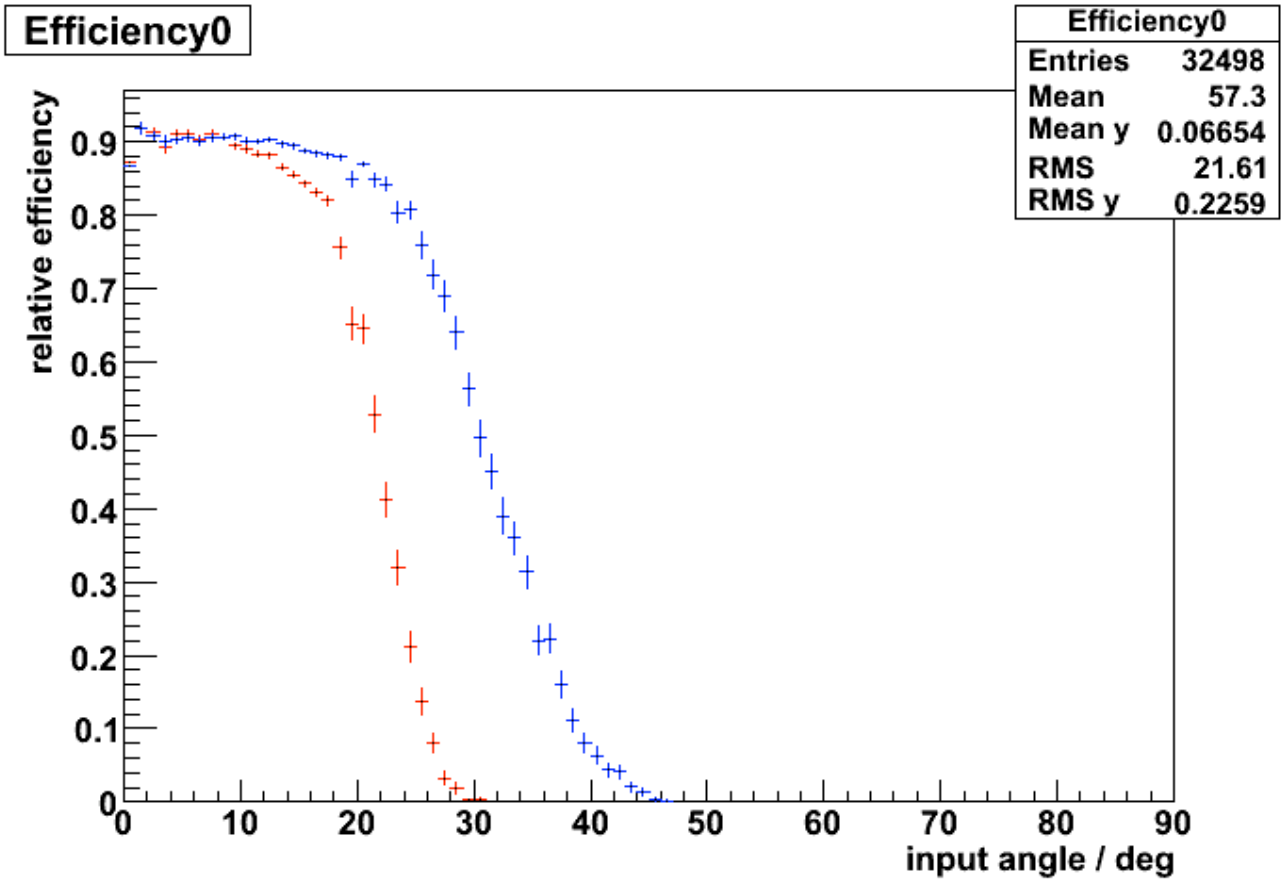
Di/mm	ε/%
4	86.7
6	88.3
8	87.2
10	75.2

R = 95%

Do = 2.7 mm

h = 20 m

Comparison open-solid



hex-square
R = 95%
Di = 7.62 mm
Do = 2.8 mm
h = 20 m

open: 83.9% / 82.1% efficiency
solid: 89.1% / 88.0 % efficiency

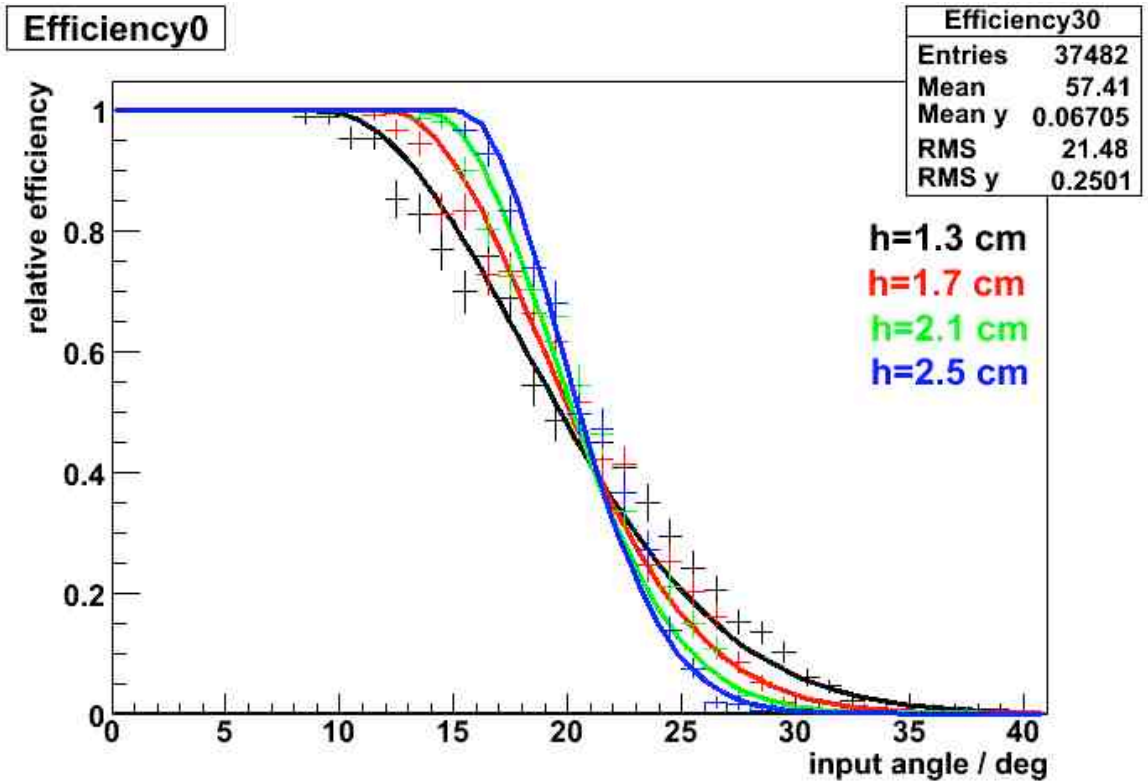
Height Optimization

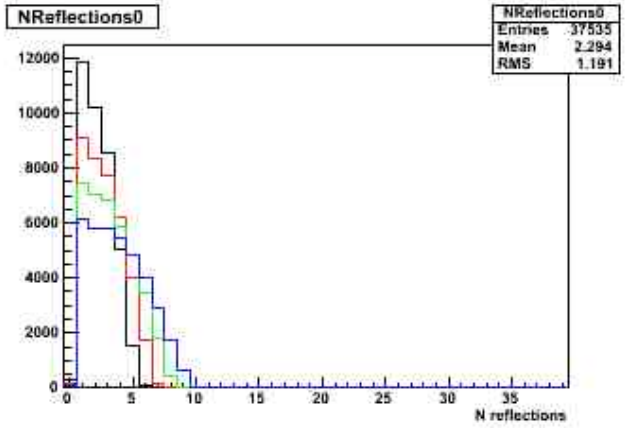
with increasing h:

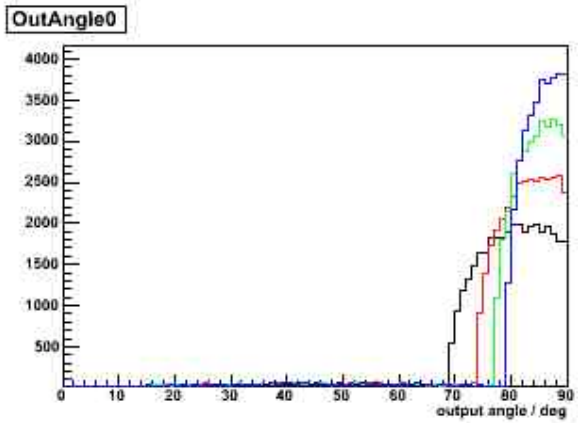
-efficiency increases, but also N_refl, output angle

-no strong movement of intrinsic fov angle

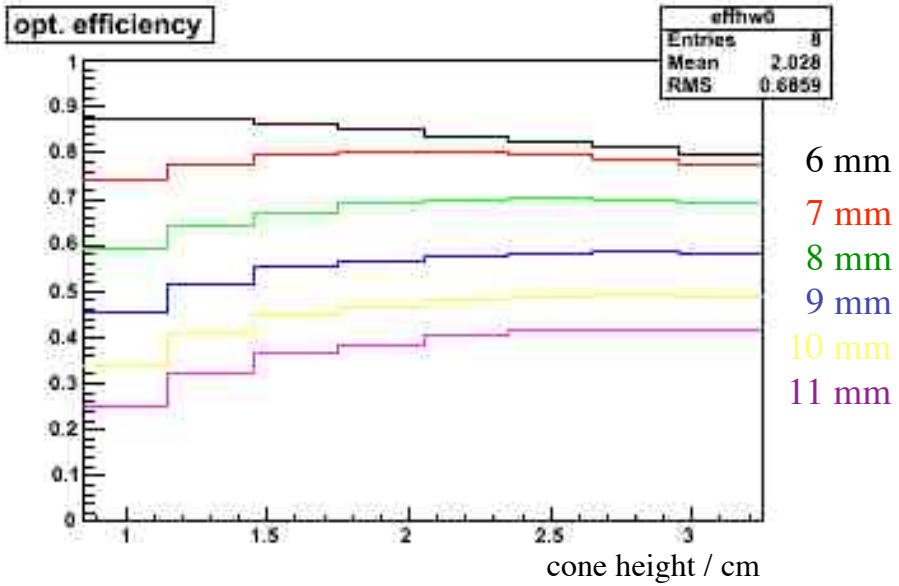
(flat sq-sq, Di=0.762 cm, Do=0.28 cm, CutAngle 80 deg)

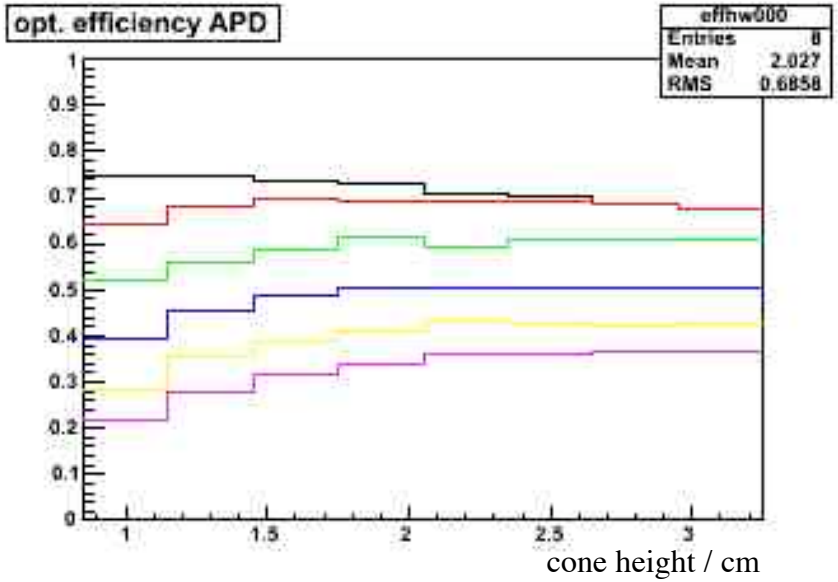






Optimize: Hollow flat, 95%





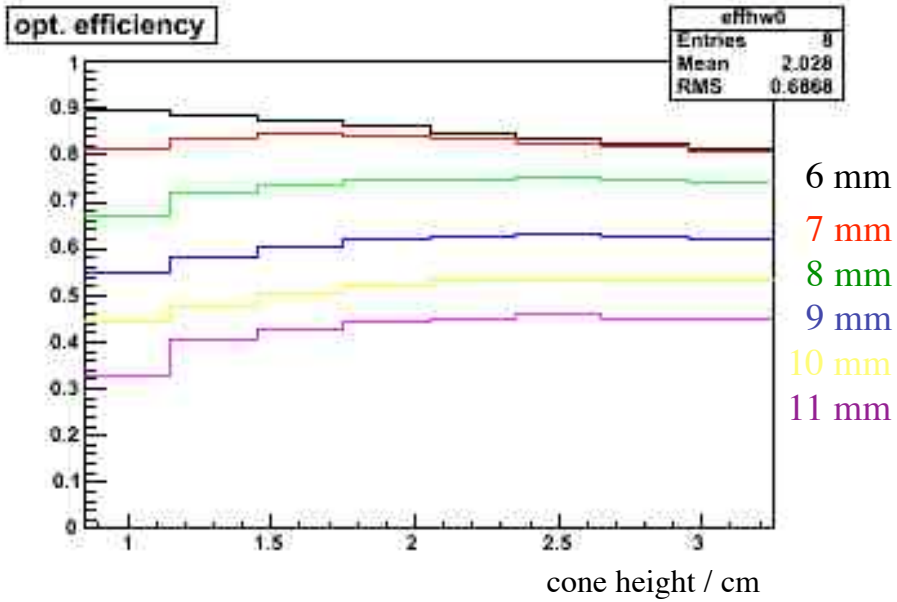
offener Pyramidenstumpf

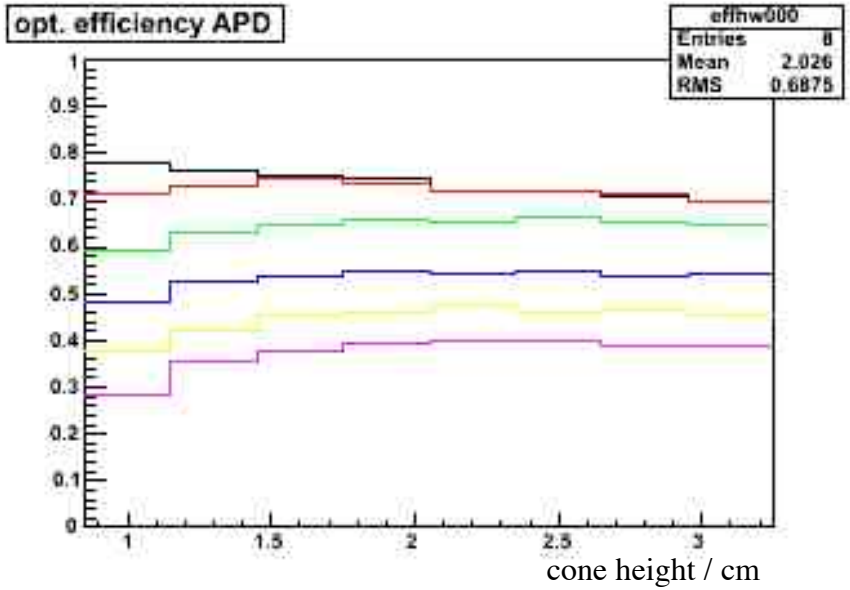
Maximum:

6 mm (1 cm) - 74.5 %

7 mm (1.6 cm)- 70.0 %

Hollow square parabolic, 95%





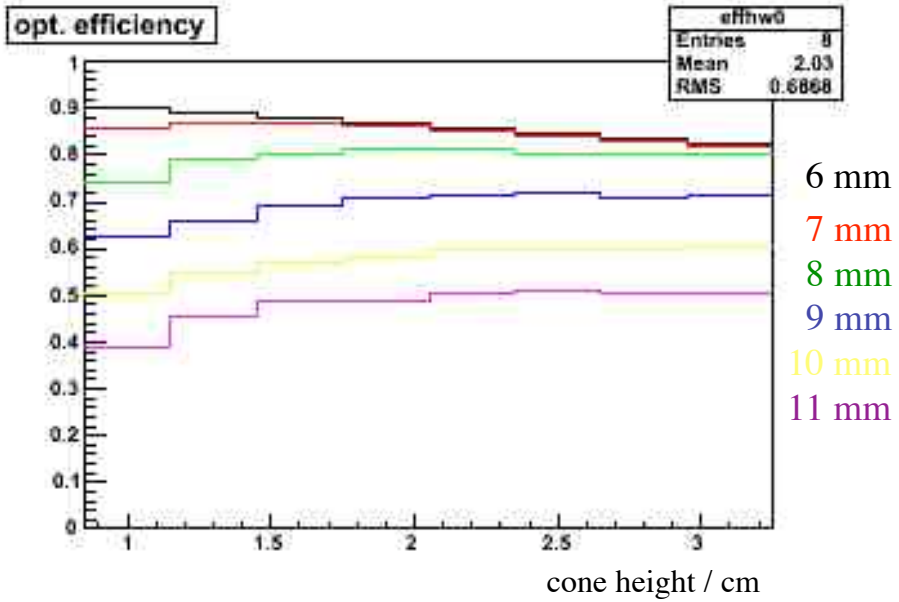
offen, quadr. Grundflaeche,
parabolische Seitenflaechen

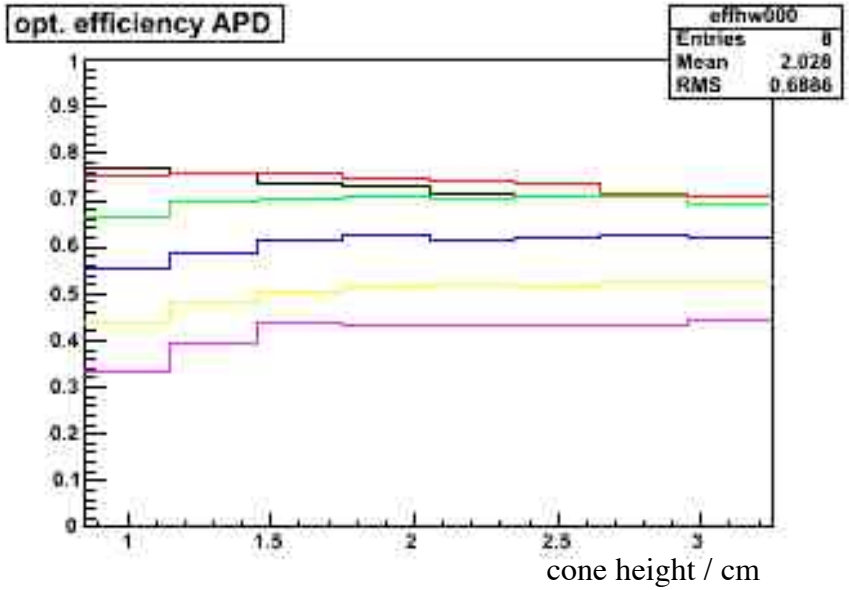
Maximum:

6 mm (1 cm) - 78 %

7 mm (1.6 cm)- 75 %

Hollow hex parabolic, 95%





offen, hex. Grundflaeche,
parabolische Seitenflaechen

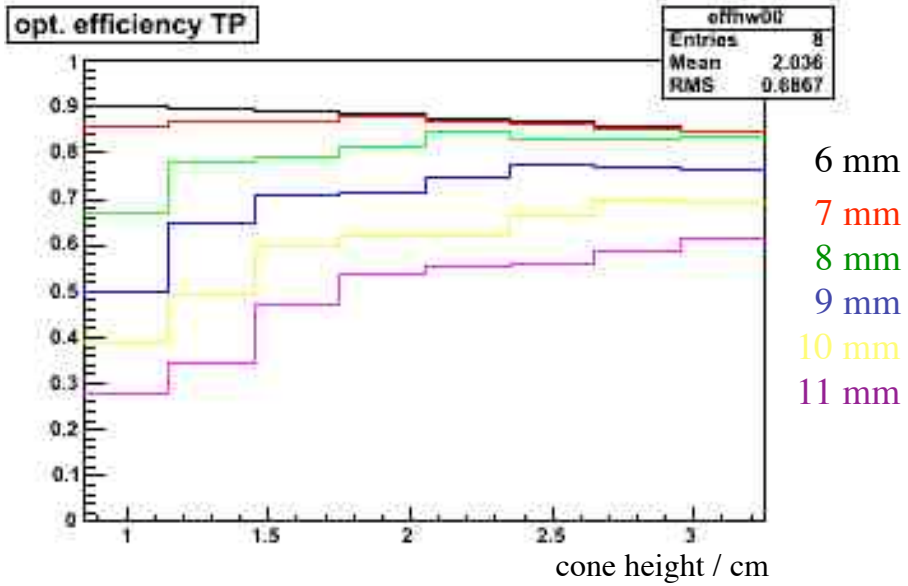
Maximum:

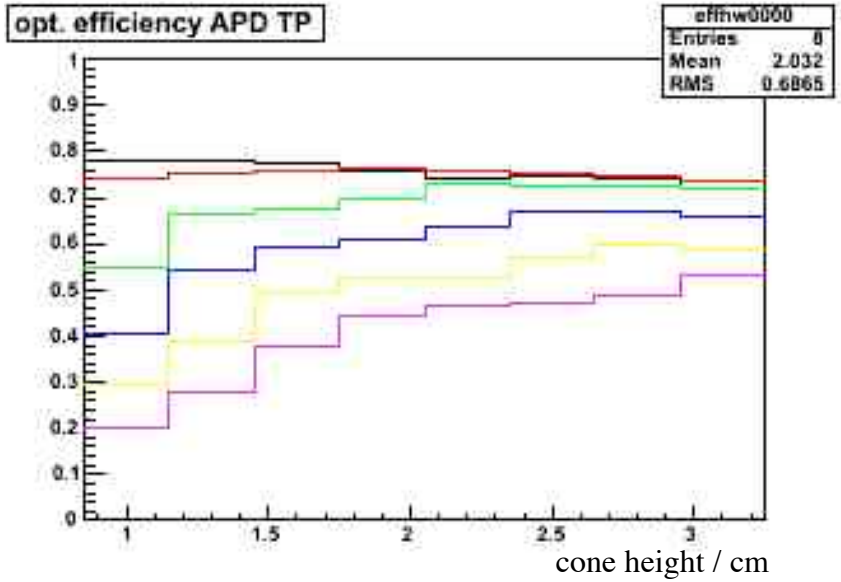
6 mm (1.0 cm)- 77%

7 mm (1.6 cm)- 76%

8 mm (2.5 cm)- 71%

Solid flat, 95%





glaeserner Pyramidenstumpf

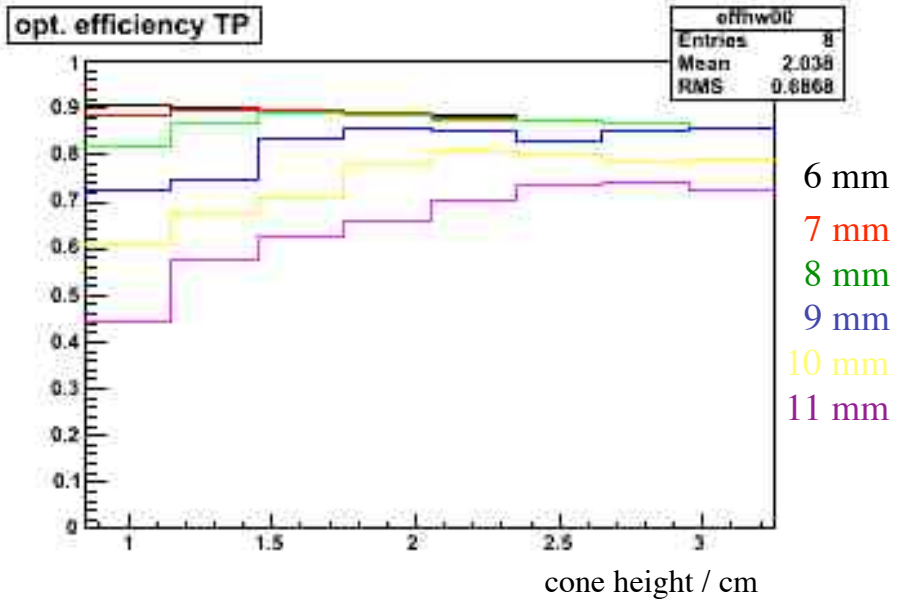
Maximum:

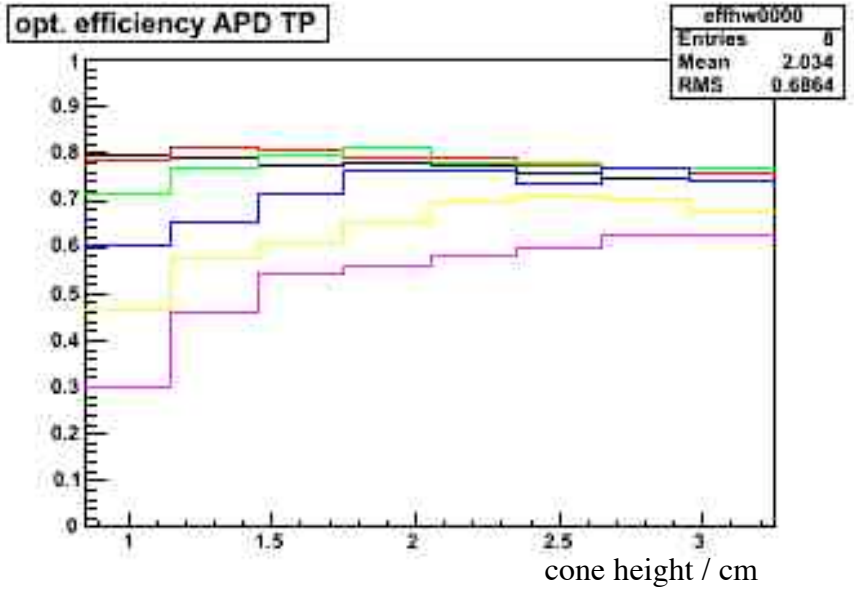
6 mm (1 cm) - 78.0 %

7 mm (1.9 cm)- 78.5 %

8 mm (2.2 cm)- 73.0 %

Solid square parabolic, 95%





Glas, quadr. Grundflaeche,
parabolische Seitenflaechen

Maximum:

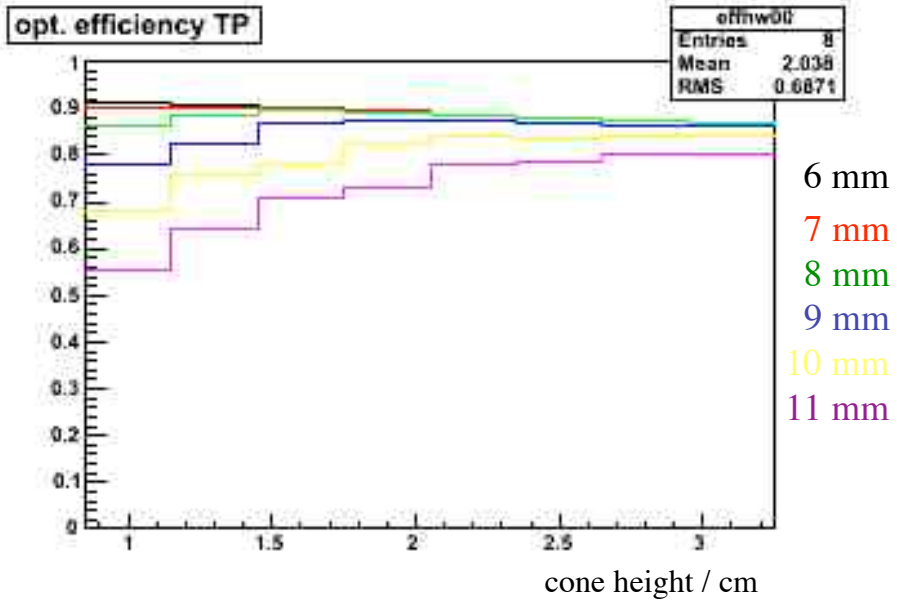
6 mm (1 cm) - 79.5 %

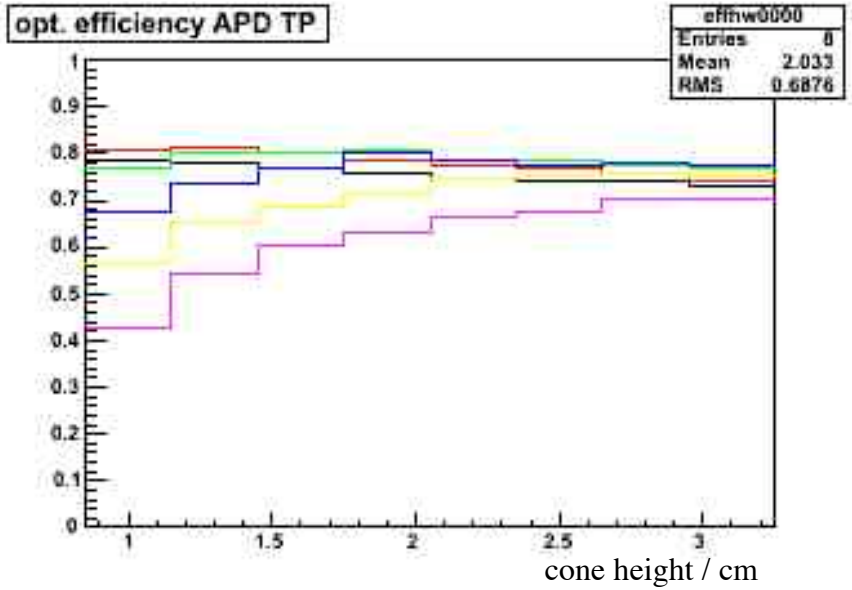
7 mm (1.3 cm)- 81.0 %

8 mm (1.9 cm)- 81.5 %

9 mm (2.8 cm)- 77.0 %

Solid hex parabolic, 95%





Glas, hex. Grundflaeche,
parabolische Seitenflaechen

Maximum:

6 mm (1.0 cm)- 78.5 %

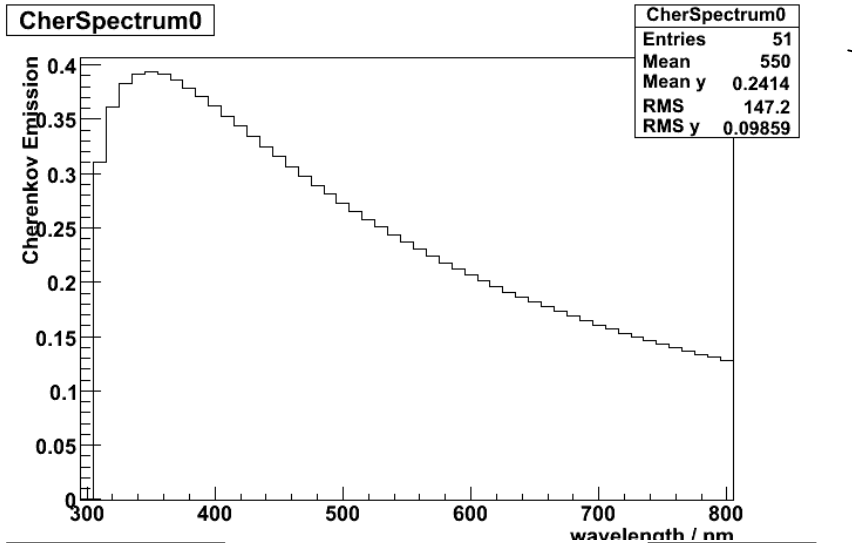
7 mm (1.3 cm)- 81.5 %

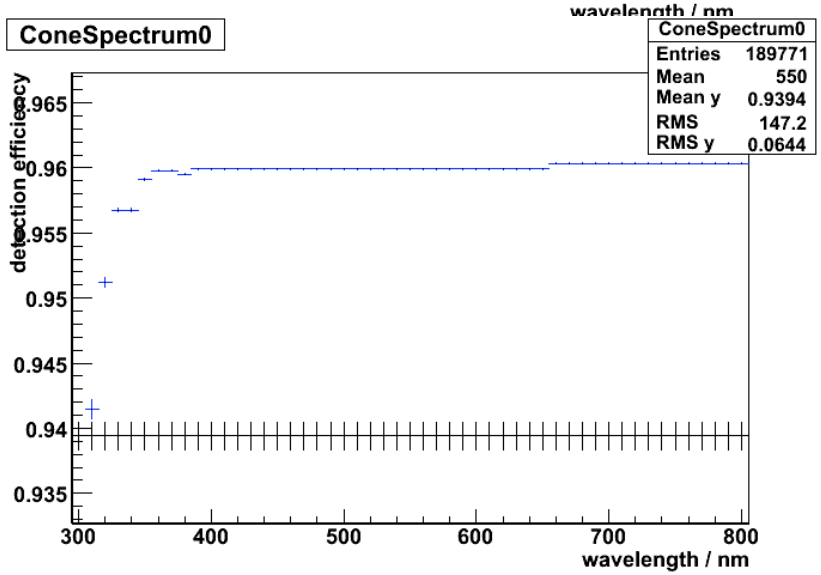
8 mm (1.9 cm)- 81.0 %

9 mm (1.9 cm)- 80.0 %

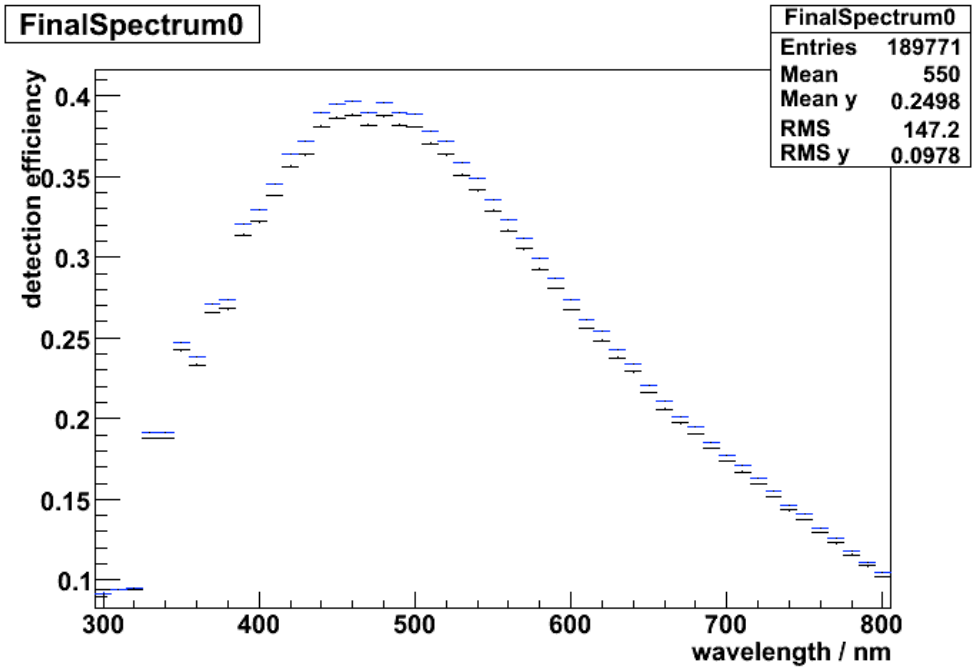
1 cm (2.8 cm) - 75.5 %

Spectral acceptace





+ APD spectral response



Summary

Cones for M0: open pyramids

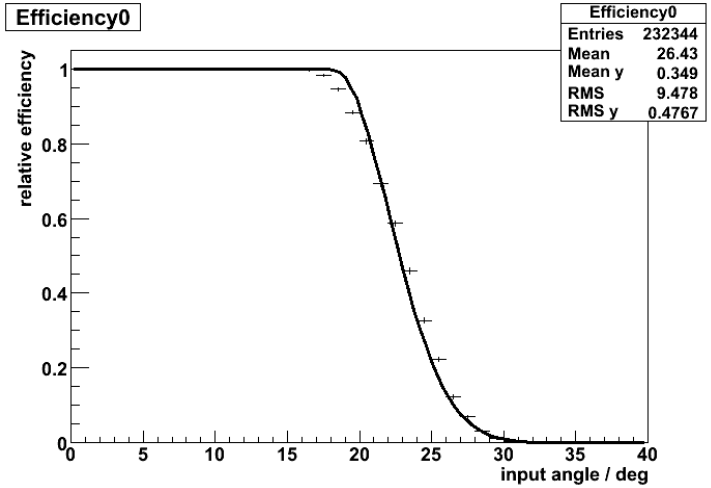
Cameras: use solid cones for larger area concentration
-> cheaper camera
good performance of hex-square geometry
transmission OK down to 300 nm (or lower)
reduces Fresnel losses
can be combined with protective window

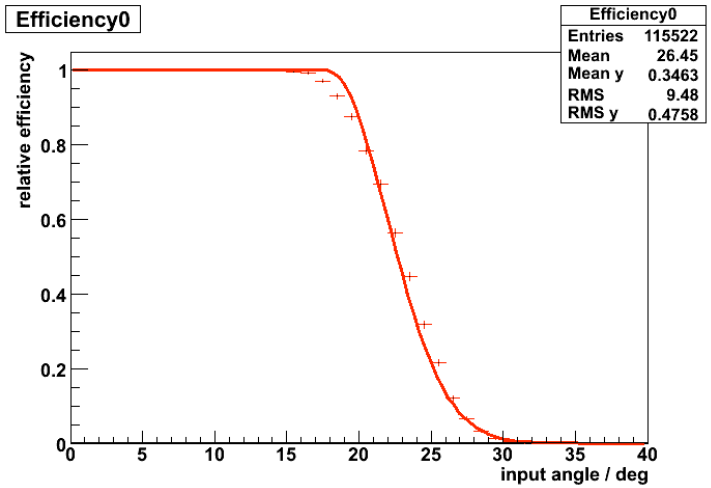
Additional Tests Implemented

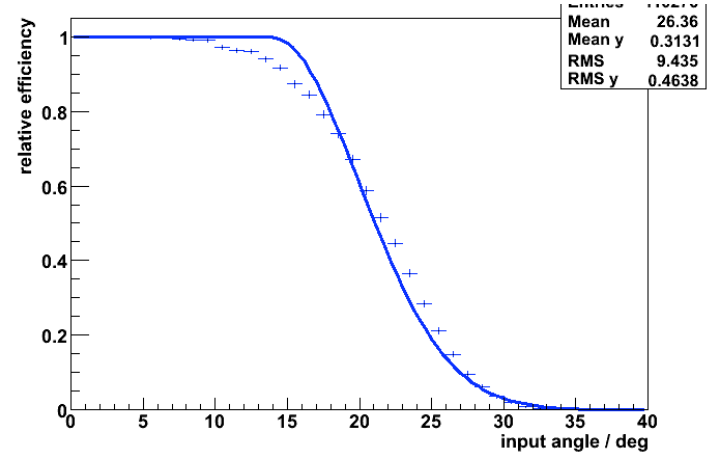
Surface flatness

regions of different refractive index

simulations for non-flat angluar response of detector







Surface Roughness

simulated by jitter in surface normal

0%: 7.85/10.85

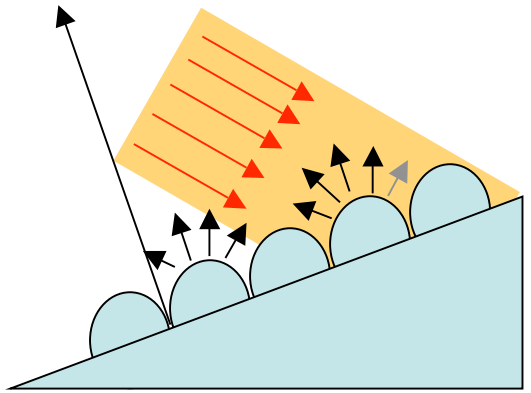
10%: 7.83/10.79

50%: 7.08/ 9.66

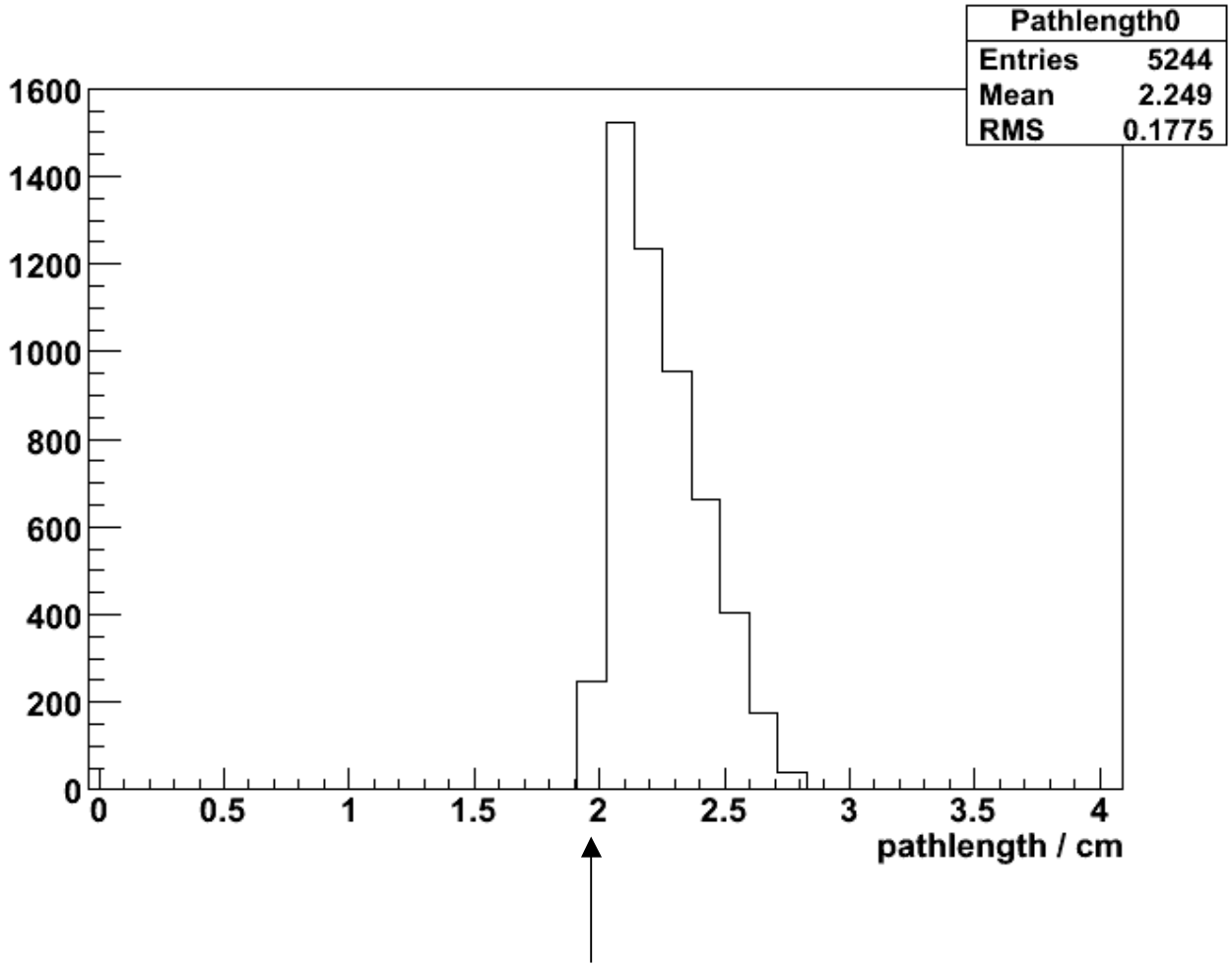
but meaning of % values not well defined yet
wanted s.th. like grain size...

are areas scattering away
from incidence direction
shaded? -> prefered backscatter?

also implemented:
„height jitter“,
but very sensitive
to „baselength“

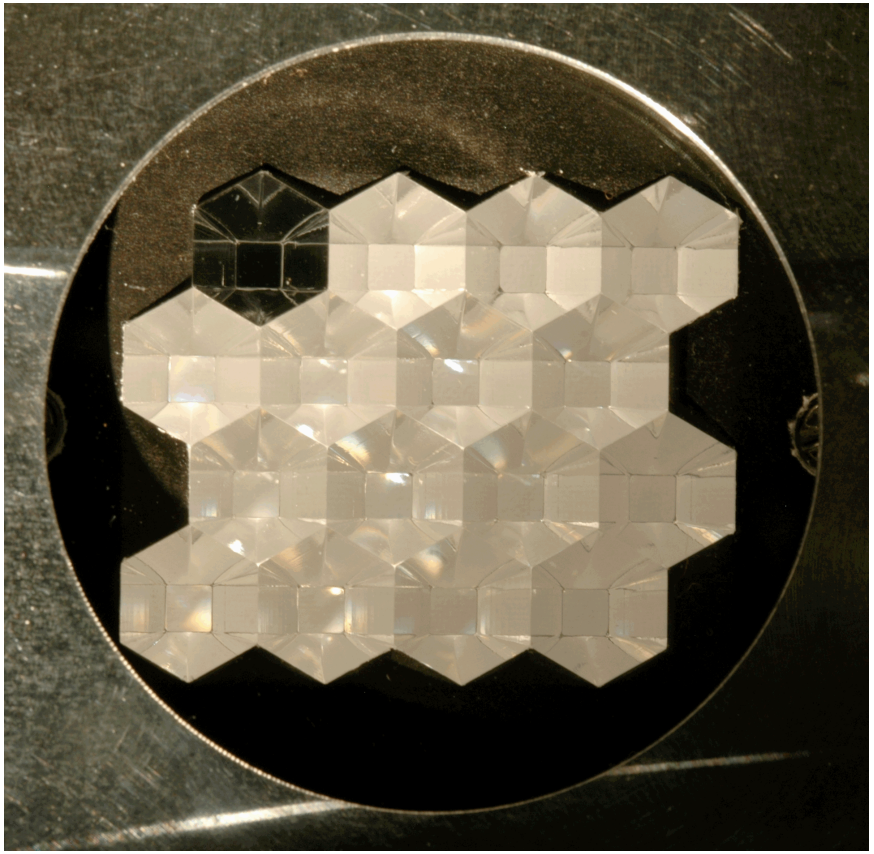


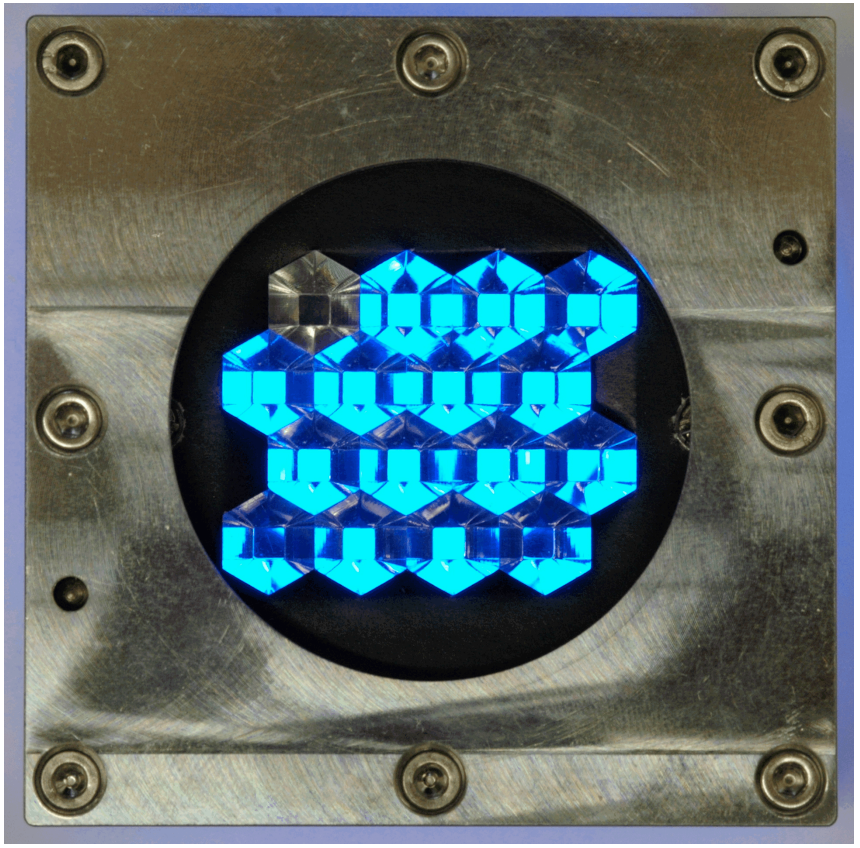
Time Dispersion



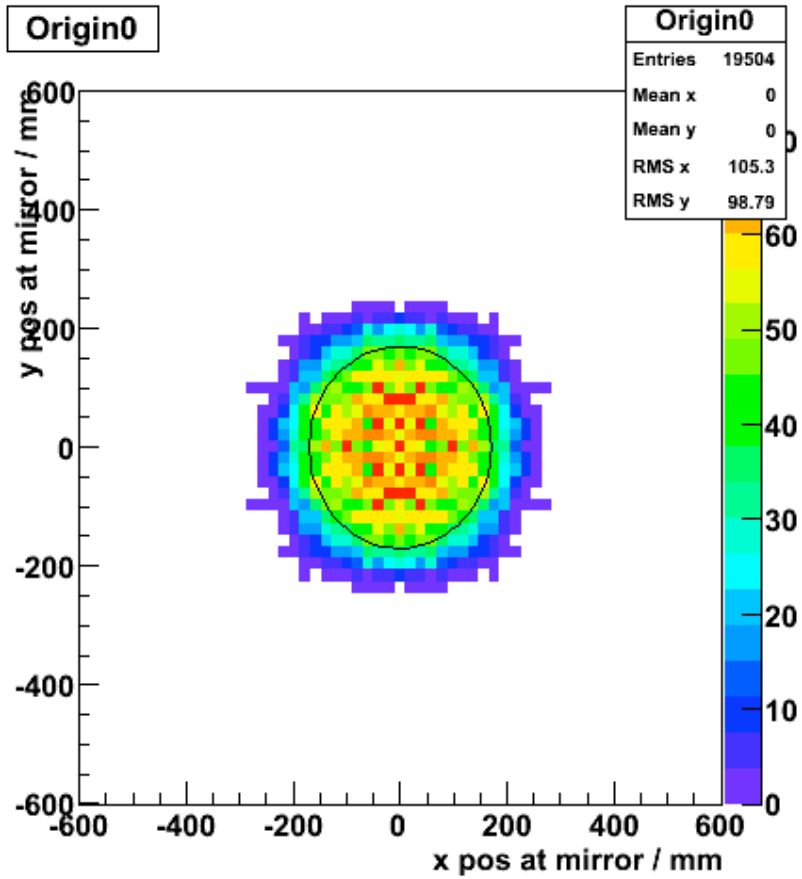
path difference < 50 % of the cone length -> less than 30 ps -> no problem!

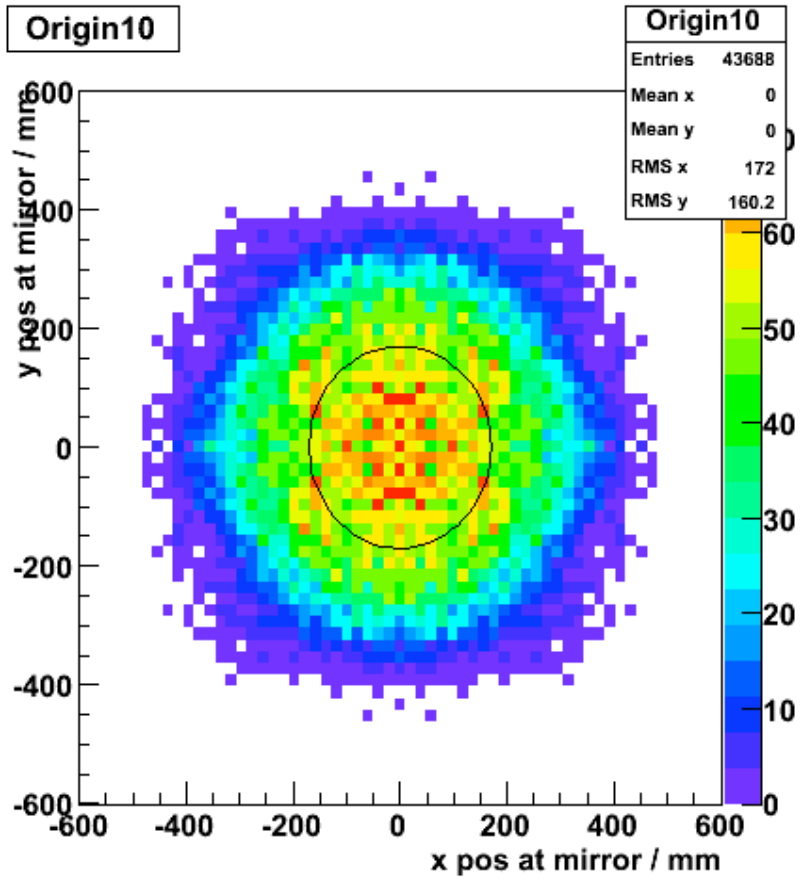
Test "Camera" (Uni ZH)





Total reflection cones





Proposed Strategy

Module 0: simple, quadratic cones with minimal outer size (7.2 mm)
(in order to have an option we can produce in house if necesary)

In parallel: order Schott UV-glass, test in house

Final Camera: order (optimal?) cones if tests are successful

Price (Achim Vollhardt)
small quantities: 500-1000,- Euro per piece
>64 : mold production - 4000 / 40 000,- mold
+ <500,- per piece
large quantities(>1000): mold + 5-10,- per piece
delivery time 8 weeks